



WL-TR-93-3513

EVALUATION OF THE RANGE QUEEN KITCHEN RANGE FIRE EXTINGUISHING DEVICE

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Contract No. F08635-93-C-0020

February 2013

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88ABW-2013-0742, 14 February 2013.

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REPORT DOCUMENTATION PAGE				<i>Form Approved OMB No. 0704-0188</i>	
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1. REPORT DATE (DD-MM-YYYY) 14-FEB-2013		2. REPORT TYPE Final Technical Report		3. DATES COVERED (From - To) 11-JAN-1993 -- 27-FEB-1993	
4. TITLE AND SUBTITLE Evaluation of the Range Queen Kitchen Range Fire Extinguishing Device				5a. CONTRACT NUMBER F08635-93-C-0020	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER 0909999F	
6. AUTHOR(S) *Rocheftort, Michael A.; *Dees, Billy R.; ^Vickers, Richard N.				5d. PROJECT NUMBER GOVT	
				5e. TASK NUMBER D0	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) *Applied Research Associates P.O. Box 40128 Tyndall Air Force Base, FL 32403				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) ^Wright Laboratory 139 Barnes Drive, Suite 2 Tyndall Air Force Base, FL 32403-5323				10. SPONSOR/MONITOR'S ACRONYM(S) WL/FIVCF	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S) WL-TR-93-3513	
12. DISTRIBUTION/AVAILABILITY STATEMENT Distribution A: Approved for public release; distribution unlimited.					
13. SUPPLEMENTARY NOTES Ref Public Affairs Case # 88ABW-2013-0742, 14 February 2013. Document contains color images.					
14. ABSTRACT <p>A full-scale performance evaluation of the Range Queen kitchen range fire extinguishing device was conducted. Test conditions were selected to be typical of field situations. A full-scale mock-up of a typical military family housing kitchen was constructed specifically for this test series. The kitchen mock-up consisted of a range with an externally vented hood, both upper and lower cabinets with a counter top, and a partial ceiling. Tests were conducted using both electric and gas ranges. Six different cooking vessels were used for the tests. Tests were conducted using both vegetable oil and peanut oil as the fuel. Oil depths varied from 1/2 inch to 2 inches, depending on pay type. Range Queen extinguisher performance was found to be a function of several variables, including: range type (gas, electric), characteristics of the cooking vessel (geometry, size, material), burner size, burner location (front, rear), quantity of oil, cause of ignition, and extinguisher placement. More than 130 range-top fire tests were conducted to characterize the influence of each of these variables.</p>					
15. SUBJECT TERMS range-top fires, Range Queen extinguishers					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT UU	18. NUMBER OF PAGES 45	19a. NAME OF RESPONSIBLE PERSON Richard N. Vickers
a. REPORT U	b. ABSTRACT U	c. THIS PAGE U			19b. TELEPHONE NUMBER (Include area code)

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PREFACE

This report was prepared by Applied Research Associates, Inc., Bldg. 1142, Tyndall Air Force Base, Florida 32403, for the Wright Laboratory, Airbase Systems Branch, Fire Protection & Crash Rescue Systems Section (WL/FIVCF), 139 Barnes Drive, Suite 2, Tyndall Air Force Base, Florida 32403-5323. The work was accomplished under Scientific and Engineering Technical Assistance (SETA) contract number F08635-93-C-0020.

This test program was completed in support of HQ AFCESA/DF at the request of HQ USAF/CE. Testing was conducted between 11 January and 27 February 1993 at Tyndall Air Force Base, Florida. The HQ AFCESA/DF project officer was Mr. Fred K. Walker. The Air Force project director was Mr. Richard N. Vickers, Chief, WL/FIVCF.

EXECUTIVE SUMMARY

A. OBJECTIVE

The objective of this test series was to characterize the performance of the Range Queen® kitchen range fire extinguishing device. The test series was designed to clarify differences between reported Air Force field experience and documented laboratory testing. This research was requested by HQ USAF/CE.

B. BACKGROUND

Pyro Control, Inc. Range Queen units are automatic extinguishing systems designed for installation inside a kitchen range hood to extinguish and control range-top fires. The extinguishers contain 8 ounces of fire-extinguishing powder (93 percent sodium bicarbonate). They are activated via a heat-sensitive triggering device. When the heat-sensing actuator is triggered (by direct flame or by heat exceeding 310°F) it peels open the prescored surface on the end of the cylinder. The fire-extinguishing powder flows through the openings of the cylinder and lands on the flame directly below. According to the manufacturer's literature, the extinguishers should be positioned 12 to 18 inches above the burner surface between burners; and coverage is such that one extinguisher can guard two burners.

Range Queen kitchen range fire extinguishing devices are in wide use in the Air Force. It is estimated that as many as 20,000 units may currently be in place. HQ USAF/CE has recently received a claim that the devices will not perform properly since they have not been installed in full compliance with the installation parameters specified by Factory Mutual Research Corporation (FMRC). Specifically, FMRC requires that units be attached to the vent hood centered above each burner on each side of the stove 12 - 18 inches above the cooking surface. This installation procedure is not being strictly followed. However, Air Force experience has shown that the units are generally performing satisfactorily. The conflicting positions may be due to the fact that laboratory tests are not accurately representing typical kitchen range fire scenarios.

C. SCOPE

A full-scale performance evaluation of the Range Queen kitchen range fire-extinguishing device was conducted. Test conditions were selected to be typical of field situations. A full-scale mock-up of a typical military family housing kitchen was constructed specifically for this test series. The kitchen mock-up consisted of a range with an externally vented hood, both upper and lower cabinets with a counter top, and a partial ceiling. Tests were conducted, using both electric

and gas ranges. The top of the range hood was located 24 inches above the cooking surface. At this range hood height the Range Queen heat sensor is approximately 22 inches above the burner surface. Tests were conducted using two extinguishers and four extinguishers under the range hood. For the dual extinguisher tests, one extinguisher was placed on each side of the hood, centered between the front and rear burners. This is the standard configuration used in Air Force family housing. For the quad extinguisher tests, one extinguisher was attached directly over each burner. This configuration corresponds to the FMRC specification. Six different cooking vessels were used for the tests: 10-inch stainless steel fry pan, 10-inch cast iron fry pan, 13-inch cast iron fry pan, 10 1/2-inch tapered stainless steel sauce pan, 10-inch stainless steel sauce pan, and 7 1/4-inch stainless steel sauce pan. Tests were conducted using both vegetable oil and peanut oil as the fuel. Oil depths varied from 1/4 inch to 2 inches, depending on pan type.

D. CONCLUSIONS

Range Queen extinguisher performance was found to be a function of several variables, including: range type (gas, electric), characteristics of the cooking vessel (geometry, size, material), burner size, burner location (front, rear), quantity of oil, cause of ignition, and extinguisher placement. More than 130 range-top fire tests were conducted to characterize the influence of each of these variables. The conclusions of this research effort are summarized below:

- This test program confirmed that Range Queen extinguishers (centered between burners) will initially extinguish many common range-top fires. However, if the heat source is not disconnected, reignition will occur in many cases.
- The agent/oil ratio is the key to initial extinguishment and sustained fire suppression. Fires are not extinguished and controlled unless the quantity of agent entering the pan is sufficient to neutralize the oil. Since Range Queen extinguishers contain only 8 ounces of agent (and only a portion of this actually enters the pan), they are capable of extinguishing only moderate volumes of burning oil.
- Range Queen units perform best on fires in large diameter, shallow fry pans, containing a limited amount of oil. (The specific amount of oil depends on the range type.) The large opening allows a significant quantity of agent to reach the oil. Fires in deep, small diameter sauce pans are the most difficult to extinguish.
- Range Queen extinguisher performance is poor on gas ranges. Gas range burners supply more heat to the pan. Due to the greater heat source, gas range fires are more difficult to extinguish, and tend to reignite in a shorter period of time. In the current Air Force

configuration (centered between burners) this unit is incapable of extinguishing a 5-ounce (1/4-inch) autoignited oil fire in a 7 1/4-inch sauce pan.

- Testing demonstrated that Range Queen extinguishers will extinguish the gas burner in certain situations. In several tests, the gas burner was extinguished, while the fire in the pan was not. Since the flow of gas continues after burner extinguishment, this phenomenon creates a potentially dangerous situation.
- Placing Range Queen units above each burner is not advisable. Although more agent does enter the pan, the agent often enters the pan with sufficient velocity to splash oil out of the pan. Splash-out often results in nearly immediate reignition on gas ranges. Also, depending on the geometry of the range hood, it is often impossible to locate units directly over the front burners.
- "Screened" Range Queen units offer little advantage. The performance of the screened units placed over the burners was basically the same as for standard units centered between burners. One or more agent outlet ports failed to open in each test. Since a significant quantity of agent remains trapped inside the extinguisher, this defeats the purpose of locating the extinguisher over the burner.

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SECTION I INTRODUCTION

A. OBJECTIVE

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lower cabinets with a counter top, and a partial ceiling. Tests were conducted using both electric and gas ranges. The top of the range hood was located 24 inches above the cooking surface. At this range hood height the Range Queen heat sensor is approximately 22 inches above the burner surface. Tests were conducted using two extinguishers and four extinguishers under the range hood. For the dual extinguisher tests, one extinguisher was placed on each side of the hood, centered between the front and rear burners. This is the standard configuration used in Air Force family housing. For the quad extinguisher tests, one extinguisher was attached directly over each burner. This configuration corresponds to the FMRC specification. Six different cooking vessels were used for the tests: 10-inch stainless steel fry pan, 10-inch cast iron fry pan, 13-inch cast iron fry pan, 10 1/2-inch tapered stainless steel sauce pan, 10-inch stainless steel sauce pan, and 7 1/4-inch stainless steel sauce pan. Tests were conducted using both vegetable oil and peanut oil as the fuel. Oil depths varied from 1/4 inch to 2 inches, depending on pan type.

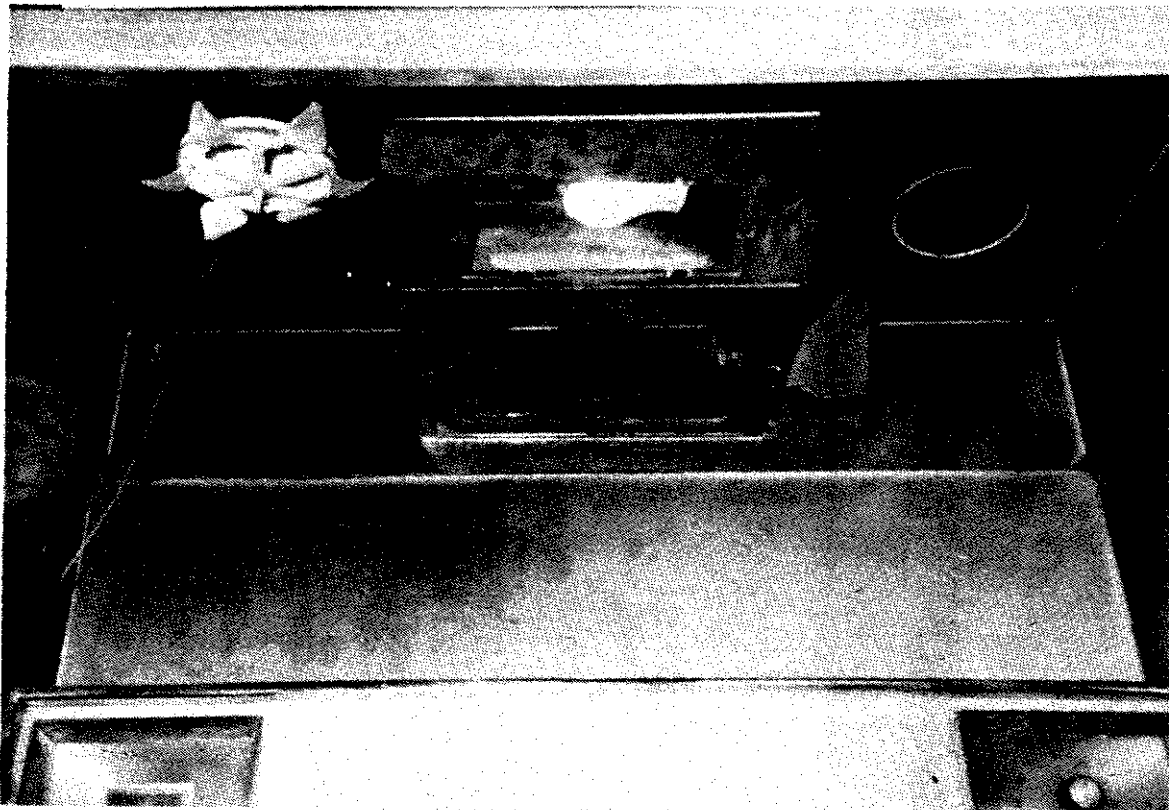


Figure 1. Range Queen Kitchen Range Fire-Extinguishing Device

SECTION II

FIELD SURVEY OF RANGE QUEEN PERFORMANCE

A. INTRODUCTION

As stated previously, Range Queen kitchen range extinguishers are being widely used throughout the Air Force. A limited phone survey was conducted to document field performance of these units. Twelve Air Force bases currently using Range Queen extinguishers were contacted. A list of the 12 bases, and the name of the point of contact at each base is given below:

<u>Air Force Base</u>	<u>Point of Contact</u>
Columbus AFB	TSgt Bowman
Eglin AFB	Sgt Kemp
Holloman AFB	Mr Carr
Keesler AFB	Sgt Garman
Kelly AFB	MSgt Humphrey
Laughlin AFB	Mr Dukes
Los Angeles AS	Mr Southerlin
McClellan AFB	Mr Bockman
Randolph AFB	Mr Grazani
Robins AFB	Mr Barnett
Tinker AFB	Chief Barnett
Vance AFB	Mr Diner

Each of the individuals listed above was asked to provide all possible information pertaining to the installation and performance of Range Queen extinguishers at their base.

B. RANGE QUEEN INSTALLATION

None of the bases surveyed have installed the Range Queen units in compliance with the FMRC installation specification. Units are being installed two per range hood; one on each side of the range, centered between the front and rear burners. Although not in line with the FMRC specification, this arrangement is suggested in the manufacturer's (i.e., Pyro Control, Inc.) brochure. Extinguisher installation heights range from 23 to 28 inches (distance from the heat sensor to the cooking surface) above the cooking surface. This is greater than the 18-inch maximum installation height specified by FMRC and Pyro Control, Inc.

C. RANGE QUEEN PERFORMANCE

Despite taking liberties in installation, Range Queen extinguishers are performing very well in practice. Of the 12 bases contacted, four bases have experienced fires on Range Queen equipped ranges. These four bases reported a total of 44 range-top fires, with no reported property damage (or injuries).

The most complete case study on Range Queen field performance was provided by Mr. Joseph D. Barnett of Robins AFB. Robins AFB has approximately 1400 ranges (1101 electric, 295 gas) equipped with Range Queen extinguishers. Twenty-six range top fires have been reported since 31 October 1990. Twenty-two of the fires involved electric ranges and four involved gas ranges. Thirteen of the fires were attended and 13 were unattended. The attended fires were mainly flash fires resulting from the introduction of food (e.g., french fries, chicken) into oil which was too hot. Most of the unattended fires involved spontaneously ignited cooking oil. There was no reported damage (and no reported injuries) as a result of any of the 26 fires.

Despite these stellar reports, a word of caution is in order. The occupant always returned to the kitchen either shortly before or shortly after the Range Queen unit discharged. In several cases, the "pop" associated with the discharge of the Range Queen unit caused the occupant to return to the kitchen. In every case someone was present to either turn off the power (or gas) to the burner, remove the pan from the burner, and/or use a household extinguisher to ensure extinguishment. Reignition was manually prevented by the occupants.

SECTION III

TEST RESULTS

A. INTRODUCTION

Testing was conducted in the NATO structure located at the Pavement and Structures Test Area on Tyndall AFB, FL. A full-scale mock-up of a typical military family housing kitchen was constructed within the NATO structure. The kitchen mock-up consisted of a range with an externally vented hood, both upper and lower cabinets with a counter top, and a partial ceiling (Figure 2). Tests were conducted using both electric and gas ranges. The top of the range hood was located 24 inches above the cooking surface. At this range hood height the Range Queen heat sensor is approximately 22 inches above the burner surface. Tests were conducted using two extinguishers and four extinguishers under the range hood. For the dual-extinguisher tests, one extinguisher was placed on each side of the hood, centered between the front and rear burners. This is the standard configuration used in Air Force family housing. For the quad extinguisher tests, one extinguisher was attached directly over each burner. This configuration corresponds to the FMRC specification. Six different cooking vessels were used for the tests: 10-inch stainless steel fry pan, 10-inch cast iron fry pan, 13-inch cast iron fry pan, 10 1/2-inch tapered stainless steel sauce pan, 10-inch stainless steel sauce pan, and 7 1/4-inch stainless steel sauce pan. Tests were conducted using both vegetable oil and peanut oil as the fuel. Oil depths varied from 1/4 to 2 inches, depending on pan type.

Every effort was made to conduct tests which were representative of field conditions.

B. TEST VARIABLES

Performance of the Range Queen extinguisher (or any extinguisher, for that matter) is directly related to the severity of the fire being extinguished. It is a simple task to design experiments where the extinguisher passes superbly or fails miserably. Range Queen performance was found to be a function of several variables, including: range type (gas, electric), characteristics of the cooking vessel (geometry, size, material), burner size, burner location (front, rear), quantity of oil, cause of ignition, and extinguisher placement. The effect of each of these factors is summarized in the following paragraphs.

1. Range Type

Both electric and gas ranges are common in the Air Force. Gas and electric ranges exhibit several significant differences. The question has been raised as to whether one type of

range is inherently more susceptible to fires. Although this question may not have a definitive answer, the following discussion raises some interesting points.

The heating coils on an electric range require time to reach maximum temperature. Gas burners however, apply near maximum heat from the moment they are activated. Figure 3 shows a direct comparison of burner temperature vs. time, for gas and electric burners. Notice that the gas burner not only heats up much faster, but also achieves a greater maximum temperature (1762°F vs. 1064°F). This information leads to the hypothesis that a gas range can heat a pan of oil to it's ignition temperature faster than an electric range. This hypothesis was confirmed during testing. A 10-inch stainless steel fry pan, containing 1/4 inch of vegetable oil, placed on the large burner of the electric range; required 12 minutes to reach autoignition temperature. The same fry pan, with the same amount of oil, placed on the gas range; required only 5.5 minutes to reach autoignition temperature. The effect on fire potential could be interpreted in different ways. It could be concluded that gas ranges are more prone to fires because they can cause ignition in a shorter period of time. Alternately, since electric ranges require longer to heat up, they are more likely to be left unattended. Thus, it could be concluded that electric stoves are more susceptible to fires. This issue will probably not be resolved. Although not necessarily more prone to fires, the probability of inadvertently turning on the wrong burner, is much greater with electric ranges.



Figure 2. Test Kitchen

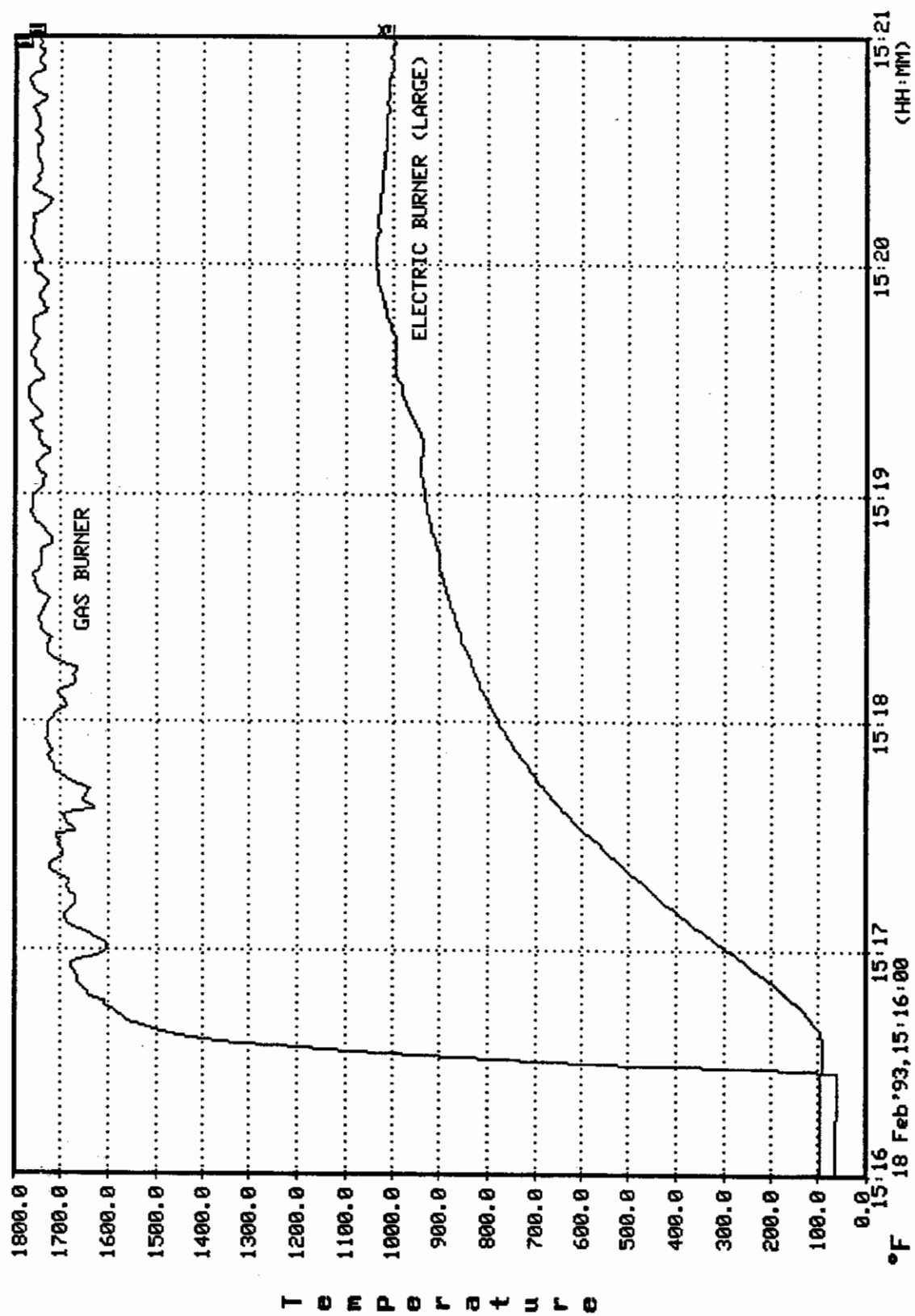


Figure 3. Burner Temperature vs. Time for Gas and Electric Ranges

Reignition is a more severe problem on gas ranges. Due to the greater intensity of the heat source on gas ranges, the time between initial extinguishment and reignition is greatly reduced.

Gas ranges are also prone to the phenomenon of splashover-induced reignition. When oil splashes over the side of a pan into the burner flame, the result is an enhanced burner flame which can engulf the pan, causing nearly instantaneous reignition. This phenomenon does not generally occur on electric ranges.

Gas ranges are susceptible to burner blow-out. Several Range Queen tests resulted in burner extinguishment. Since gas continues to flow to the burner, burner extinguishment could create a possible explosion situation.

2. Cooking Vessel Characteristics

The characteristics (geometry, size, material) of the cooking vessel have a great effect on the severity of a stove-top fire. Cooking vessels come in different styles, various sizes, and are manufactured from several materials, including: stainless steel, aluminum, cast iron, and glass. The thermodynamic properties of these materials vary significantly. The coefficients of thermal conductivity (k) of aluminum, stainless steel, and cast iron are given in Table 1, which shows that aluminum pans dissipate heat much faster than either stainless steel or cast iron pans.

TABLE 1. THERMAL CONDUCTIVITY OF TYPICAL COOKING VESSEL MATERIALS

<u>Material</u>	<u>k (Btu/h•ft•°F) @ 68°F</u>
Aluminum	132
Stainless Steel	11-42*
Cast Iron	30

* varies with the amount of Chromium

Quantity and depth of oil are related to pan type (e.g., fry pan, sauce pan) and pan size. A small diameter, shallow, fry pan, holds much less oil than a deep, large diameter, sauce pan. The larger the pan, the greater the surface area available to dissipate heat. However, larger pans also hold greater quantities of oil. The greater the quantity of oil, the more agent required to extinguish the fire.

Pan shape is also an important variable. The shape of the pan affects the quantity of agent ending up in the pan. Deep pans with vertical sides, restrict the quantity of agent entering the pan. Deep pans with tapered sides funnel the agent into the pan.

Certain combinations of pan size and pan material can produce interesting test results. It was found to be impossible to achieve autoignition of 1/4 inch of vegetable oil in a large (14-inch diameter) aluminum fry pan, placed on the large burner of the electric range. The oil reached a constant temperature of 470°F, well below autoignition temperature. The large aluminum pan was able to radiate heat at a rate fast enough to maintain a state of thermal equilibrium in the oil. This occurrence confirmed that cast iron and stainless steel pans represent a greater fire threat than aluminum pans. All tests documented in this report were conducted with stainless steel or cast iron pans.

3. Burner Size

Electric ranges are equipped with large and small burners. The larger the burner, the larger the heat source. Thus, large burners have a greater potential of initiating a fire (via autoignition). Large burners are also more likely than small burners, to re-ignite fires which were initially extinguished.

Gas ranges have four equal size burners.

4. Burner Location

Fires on the front and rear burners effect extinguisher performance differently. The hot air resulting from a range-top fire, flows outward (i.e., toward the front of the range) and upward, past the front edge of the vent hood. This air flow pattern pulls the extinguishing agent toward the front of the range. If extinguishers are mounted between the front and rear burners, this natural air flow pulls agent toward fires on the front burner, and away from fires on the rear burner.

The air flow affects agent dispersion, increases the time between ignition and extinguisher discharge. If extinguishers are centered between burners, the heat from a front burner fire flows toward the front of the range hood, away from the heat-sensitive detector on the extinguisher. This increases the response time of the extinguisher, resulting in a fire which is more well developed, and more difficult to extinguish.

5. Quantity of Oil

Tests were conducted using both vegetable and peanut oil. There appears to be no significant difference between the two oils. Both oils autoignite (i.e., spontaneously burst into flames) at a temperature of approximately 700°F.

The quantity of oil is one of the most important factors governing Range Queen extinguisher performance. The greater the quantity of oil, the more difficult the fire is to extinguish. For a fixed quantity of agent, an increase in quantity of oil, results in a lower ratio of agent to oil. Lowering the agent/oil ratio, lowers the probability of extinguishing the fire. Lowering the agent/oil ratio also decreases the time that extinguishment can be maintained (assuming the fire was suppressed in the first place).

Since the Range Queen unit contains a limited quantity of agent (8 ounces), it cannot suppress large-volume oil fires. The Range Queen unit simply does not contain enough agent to render a large quantity of oil harmless.

6. Cause of Ignition

Range-top fires generally result from one of three situations: The first situation is where cooking oil is splashed or spilled on a hot burner. In the second situation, a pan of cooking oil flashes due to the rapid introduction of food. The third situation occurs as a result of heating the oil to its autoignition temperature. Once this temperature is achieved, the oil spontaneously bursts into flames.

Fires resulting from autoignition of oil represent the worst-case situation. The cooking oil in this case is in excess of 700°F, and therefore much more likely to reignite than in the case of a fire caused by spillage of oil; or a flash fire resulting from the introduction of water into the oil such as when french fries, frozen potato balls, or chicken are rapidly introduced into the oil. Fires resulting from the introduction of food to hot oil generally occur when the oil temperature is approximately 550°F. Since the oil temperature is well below the autoignition temperature, these fires will not readily flash back.

7. Extinguisher Placement

As mentioned in the Introduction, there are two schools of thought regarding proper extinguisher placement. Factory Mutual Research Corporation insists that units be placed directly over each burner. (It should be noted that positioning the extinguishers directly over the front burners may be impossible with certain range/hood combinations.) Pyro Control, Inc. suggests centering the extinguishers between the front and rear burners, on each side of the range. Air Force installation has followed the Pyro Control philosophy.

Most of the tests were conducted with the Range Queen units centered between the burners. Several tests were also conducted with extinguishers directly over each burner. Each arrangement has positive and negative aspects. Placing the extinguisher directly over the burner results in more agent entering the pan. This is positive, since it increases the ratio of agent

to oil. This is especially important for gas ranges, due to the greater heat source. More agent is required to extinguish, and prevent re-ignition, of gas range fires. However, with the extinguisher directly over the pan, the agent often enters the pan with enough force to splash oil out of the pan. This is a serious drawback, especially for autoignition fires on gas ranges; where splash-out can result in near immediate re-ignition.

Because of the splash-out problem, Pyro Control, Inc. advises against placing standard Range Queen extinguishers directly above the burner. To correct the splash-out problem, Pyro Control has modified the standard Range Queen unit by placing a screen in front of the agent outlet ports. The screen reduces the velocity with which the agent is discharged.

C. RESULTS (STANDARD RANGE QUEEN UNITS)

This section documents the results of all tests conducted using standard Range Queen extinguishers (121 tests). One-hundred and two tests were conducted with the units centered between the front and rear burners, and 19 tests with the units directly over the burners. The electric range was used for 87 tests, while 34 tests were conducted on the gas range. For every test, the oil was allowed to spontaneously autoignite. This represents a severe, yet realistic situation.

Before presenting the tabulated test results, let's briefly discuss the information common to each table. Each table contains the following information: location of the Range Queen units (unit centered between burners, unit over burner), range type, burner description (large, small, front, rear), pan description, type and depth of oil, and the test results. Annotations are used to discuss peculiar results, if any. Six pans were used during the course of the testing (Note: D_T = diameter at top of pan, D_B = diameter at base of pan):

- 10-inch Stainless Steel Fry Pan (10-inch D_T , 8 3/4-inch D_B , 2 inches deep)
- 10-inch Cast Iron Fry Pan (10-inch D_T , 8 3/4-inch D_B , 2 inches deep)
- 13-inch Cast Iron Fry Pan (13-inch D_T , 11-inch D_B , 2 1/2 inches deep)
- 10 1/2-inch Stainless Steel Sauce Pan (10 1/2-inch D_T , 7 3/4-inch D_B , 6 1/2 inches deep)
- 10-inch Stainless Steel Sauce Pan (10-inch D_T , 9 1/2-inch D_B , 4 11/16 inches deep)
- 7 1/4-inch Stainless Steel Sauce Pan (7 1/4-inch D_T , 7-inch D_B , 4 1/2 inches deep)

Photographs of each of the six pans are included as Figures 4 - 9.

Although the information is not presented in this report, each test was instrumented with thermocouples. The burner temperature, oil temperature, and the temperature at the Range Queen heat sensor location were recorded as a function of time, for each test.



Figure 4. 10-inch Stainless Steel Fry Pan



Figure 5. 10-inch Cast Iron Fry Pan



Figure 6. 13-inch Cast Iron Fry Pan

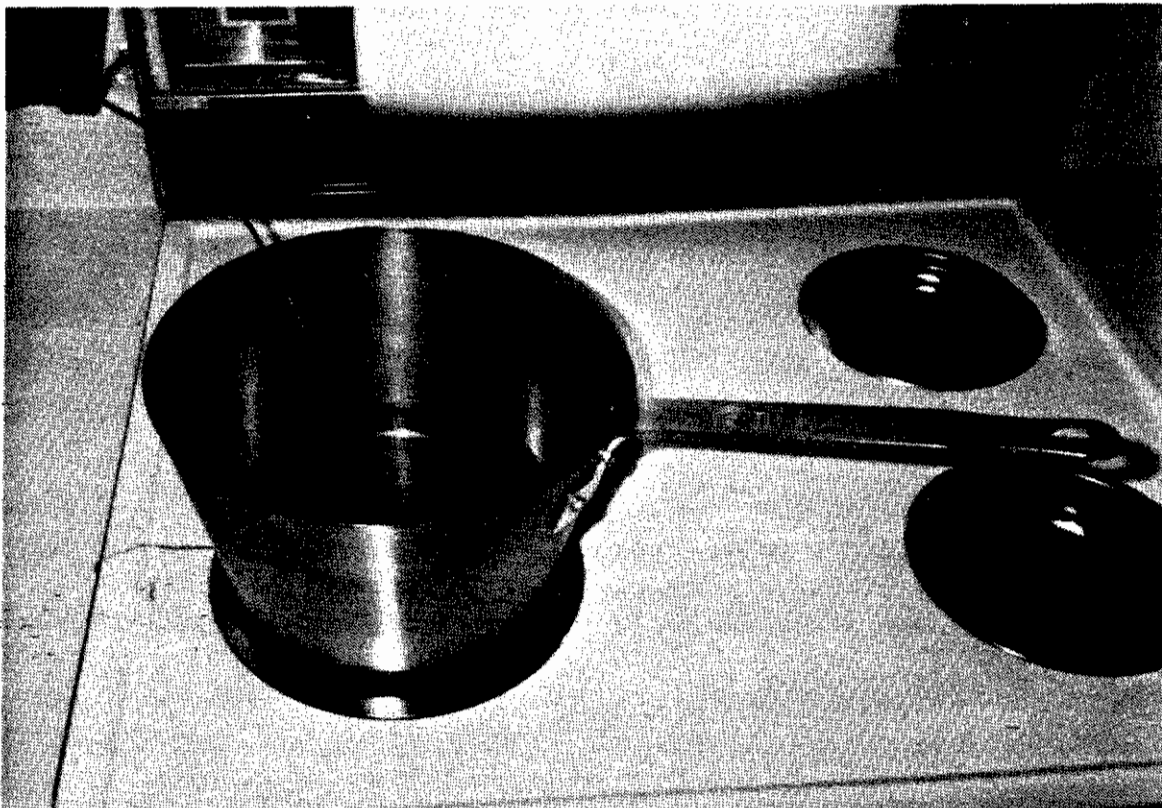


Figure 7. 10 1/2-inch Stainless Steel Sauce Pan



Figure 8. 10-inch Stainless Steel Sauce Pan

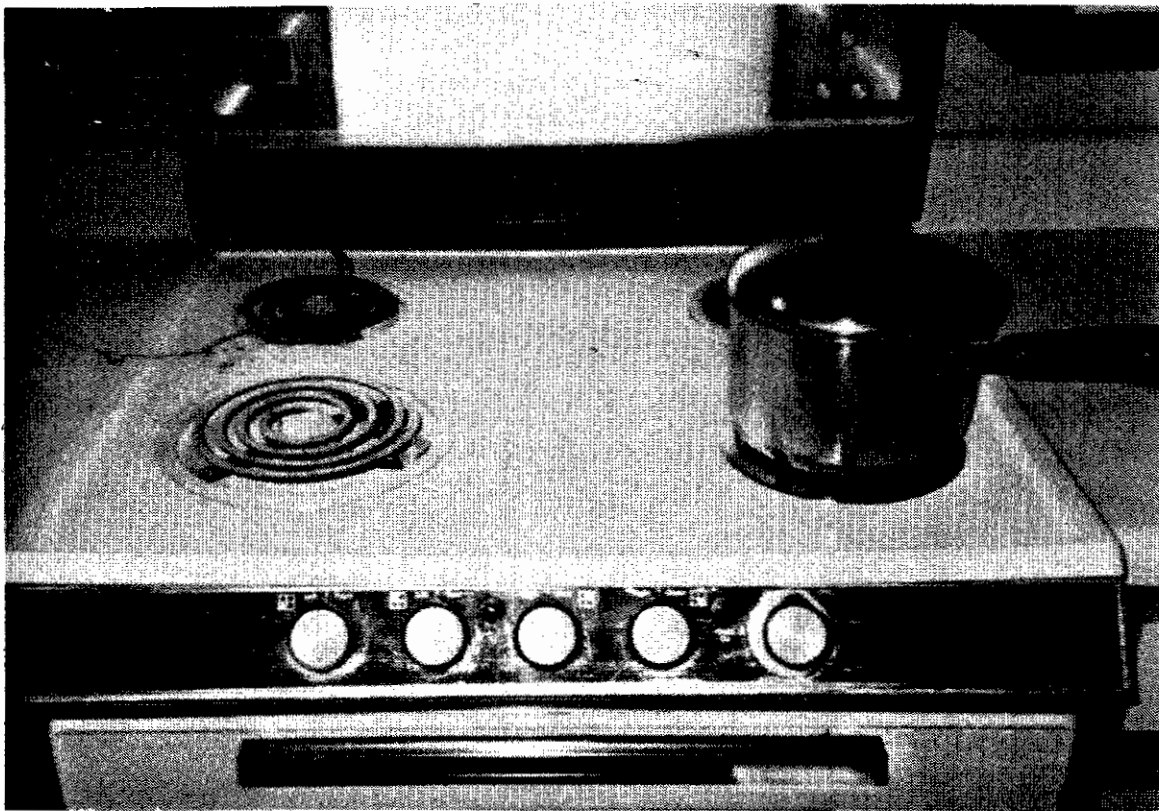


Figure 9. 7 1/4-inch Stainless Steel Sauce Pan

1. Extinguishers Centered Between Burners

Tables 2 - 13 pertain to Range Queen tests where the units were centered between the front and rear burners. Tables 2 - 10 contain results of electric range tests, while Tables 11 - 13 document gas range tests. Electric range tests were conducted using the large (left front) burner and the small (left rear) burner. Gas range tests were all conducted on the left front burner. Significant test results are discussed in the following paragraphs.

The magnitude of the heat source affects autoignition potential. The following discussion illustrates this point: The small burner of the electric range was unable to produce sufficient heat to induce autoignition of 9 ounces (1/4 inch) of oil in a 10-inch stainless steel fry pan (see Table 7). However, the large burner generates enough heat to autoignite at least 17 ounces (1/2 inch) of oil in the same pan (see Table 2). The gas range is capable of autoigniting at least 26 ounces (3/4 inch) of oil in this pan (see Table 11).

The greater the heat source, the shorter the time to reignition. Notice how the gas range requires less time than the electric range to reignite 1/2 inch of oil in the 10-inch stainless steel fry pan (see Tables 2 and 11).

Pan shape and size affect Range Queen performance. Fires in the 10-inch vertical sided sauce pan are much harder to extinguish than fires in the 10 1/2-inch tapered sauce pan (compare Tables 5 and 6). Even for small quantities of oil, fires in the 7 1/4-inch sauce pan are difficult to extinguish (see Tables 8 and 12).

Before testing, it was hypothesized that the gas burner itself might be extinguished under certain circumstances. The possibility of gas burner blow-out was confirmed. The gas burner was extinguished during each of the three consecutive tests using the 7 1/4-inch sauce pan (see Table 12). Interestingly, the pan fire itself was not extinguished. Since the flow of gas continues after burner extinguishment, burner blow-out creates a potentially hazardous situation.

Although range type, burner size, pan type, etc., are significant parameters influencing extinguisher performance, test results tend to illustrate that fire suppression and re-ignition potential are primarily governed by the agent/oil ratio. If the agent/oil ratio is very high, the fire will not reignite, regardless of heat source. If the agent/oil ratio is very low, the fire will re-ignite quickly (if it was extinguished at all). The key to Range Queen extinguisher performance is putting the maximum quantity of agent into the pan. When a sufficient quantity of agent enters the pan, the agent combines with the oil to form a giant "biscuit." When this occurs, reignition is not possible.

TABLE 2. SUPPRESSION UNIT CENTERED BETWEEN BURNERS, LARGE BURNER
ELECTRIC RANGE, FRY PAN 10-INCH (Stainless Steel)

TEST 1		TEST 2		TEST 3		TEST 4		TEST 5	
Veg Oil		Veg Oil		Peanut Oil		Veg Oil		Veg Oil	
1/4"	T-23 Put Out No Reignition	T-24 Put Out No Reignition	T-25 Put Out No Reignition						
1/2"	T-28 Did Not Put Out *	T-27 Put Out Reignition 4 min 20 sec	T-26 Put Out Reignition 1 min 40 sec	T-29 Put Out Reignition 6 min	T-30 Put Out Reignition 3 min				
1"									
2"									

* Canister only partially opened, slowing discharge

TEST 6					
Peanut Oil					
1/2"	T-34 Put Out Reignition 1 min				

TABLE 3. SUPPRESSION UNIT CENTERED BETWEEN BURNERS, LARGE BURNER
ELECTRIC RANGE, FRY PAN 10-INCH (Cast Iron)

TEST 1		TEST 2		TEST 3		TEST 4		TEST 5	
Peanut Oil		Peanut Oil		Veg Oil		Veg Oil			
1/4"	T-42 Put Out No Reignition	T-50 Put Out No Reignition		T-112 Put Out No Reignition					
1/2"	T-43 Put Out Reignition 7 min 4 sec	T-46 Put Out Reignition 2 min		T-113 Put Out Reignition 4 min 5 sec					
3/4"	T-51 Put Out Reignition 2 min 15 sec			T-52 Put Out Reignition 49 sec *		T-114 Put Out Reignition 48 sec			
2"									

* Oil splashed out and ignited under the pan causing reignition to the pan.

TABLE 4. SUPPRESSION UNIT CENTERED BETWEEN BURNERS, LARGE BURNER
ELECTRIC RANGE, FRY PAN 13-INCH (Cast Iron)

TEST 1		TEST 2		TEST 3		TEST 4		TEST 5	
Peanut Oil		Peanut Oil		Veg Oil					
1/4"	T-38 Put Out No Reignition	T-48 Put Out No Reignition	T-55 Put Out No Reignition						
1/2"	T-39 Put Out No Reignition	T-49 Put Out No Reignition	T-54 Put Out No Reignition						
1"	T-59 No Ignition *		T-10 No Ignition *						
2"									

* Since no ignition occurred, data from these tests are included with the suppression unit over burner.

TABLE 5. SUPPRESSION UNIT CENTERED BETWEEN BURNERS, LARGE BURNER
ELECTRIC RANGE, SAUCE PAN 10-INCH (Stainless Steel)

TEST 1		TEST 2		TEST 3		TEST 4		TEST 5	
Veg Oil		Veg Oil		Peanut Oil		Veg Oil		Veg Oil	
* 1/4" *	T-78 Put Out No Reignition	T-79 Put Out Reignition 5 sec	T-80 Put Out Reignition 5 sec	T-109 Put Out Reignition 6 sec	T-110 Put Out No Reignition				
1/2"	* T-76 Put Out Reignition 5 sec	** T-77 Put Out Reignition 1 min 16 sec		T-111 Put Out Reignition 1 min 3 sec					
1"									
2"	T-124 Put Out Reignition 4 min 20 sec	T-125 Put Out Reignition 4 min 25 sec		T-126 Put Out Reignition 6 sec					

* Fire Ball rolled back into pan (Front 800+)

** Insufficient agent in pan (Front 800+)

TABLE 6. SUPPRESSION UNIT CENTERED BETWEEN BURNERS, LARGE BURNER
ELECTRIC RANGE, SAUCE PAN 10 1/2-INCH (Stainless Steel)

TEST 1		TEST 2		TEST 3		TEST 4		TEST 5	
Veg Oil		Peanut Oil		Veg Oil		Peanut Oil		Veg Oil	
1/4"	T-16 Put Out No Reignition	T-17 Put Out No Reignition	T-53 Put Out No Reignition						
1/2"	T-20 Put Out Reignition 4min 42sec	T-18 Put Out Reignition 2 min 49 sec	T-19 Put Out Reignition 2 min 40 sec	T-31 Put Out Reignition 3 min	T-32 Put Out No Reignition *				
1"									
2"	T-117 Put Out Reignition 1 min 18 sec	T-37 Put Out Reignition 10 sec	T-118 Put Out Reignition 31 sec						

* Longer than normal burn time to actuating extinguisher
(Consumed Oil)

TABLE 7. SUPPRESSION UNIT CENTERED BETWEEN BURNER, SMALL BURNER
ELECTRIC RANGE, FRY PAN 10-INCH (Stainless Steel)

TEST 1		TEST 2		TEST 3		TEST 4		TEST 5	
Peanut Oil		Peanut Oil		Peanut Oil					
1/4"	T-35 No Ignition	T-36 No Ignition	T-45 No Ignition *						
1/2"									
1"									
2"									

* Oil ignited by hand to determine if small burner on rear would draft agent. It did not.

TABLE 8. SUPPRESSION UNIT CENTERED BETWEEN BURNERS, SMALL BURNER
ELECTRIC RANGE, SAUCE PAN 7 1/4-INCH (Stainless Steel)

TEST 1		TEST 2		TEST 3		TEST 4		TEST 5	
Peanut Oil		Veg Oil		Veg Oil					
1/4"	T-121 Put Out Reignition 7 sec	T-119 Put Out Reignition 4 min 58 sec	T-120 Put Out Reignition 1 min 26 sec						
1/2"	T-73 Put Out Reignition 12 sec	T-74 Put Out Reignition 3 min 50 sec	T-75 Put Out Reignition 11 sec						
1"									
2"									

TABLE 9. SUPPRESSION UNIT CENTERED BETWEEN BURNERS, SMALL BURNER
ELECTRIC RANGE, SAUCE PAN 10-INCH (Stainless Steel)

TEST 1		TEST 2		TEST 3		TEST 4		TEST 5	
Peanut Oil		Veg Oil		Veg Oil					
1/4"	T-81 No Ignition	T-82 No Ignition	T-83 No Ignition						

TABLE 10. SUPPRESSION UNIT CENTERED BETWEEN BURNERS, SMALL BURNER
ELECTRIC RANGE, SAUCE PAN 10 1/2-INCH (Stainless Steel)

TEST 1		TEST 2		TEST 3		TEST 4		TEST 5	
Veg Oil		Peanut Oil		Peanut Oil		Veg Oil		Veg Oil	
1/4"	T-21 Put Out No Reignition	T-33 Put Out No Reignition	T-56 Put Out No Reignition						
1/2"	T-22 Put Out Reignition 5 min 31sec	T-57 Put Out No Reignition	** T-115 Put Out No Reignition	T-58 Put Out No Reignition	T-116 Put Out No Reignition				
1"									
2"	T-14 No Ignition *	T-122 No Ignition *	T-123 No Ignition *						

* Since no ignition occurred, data from these test are included with suppression unit over burner.

** Vegetable Oil

TABLE 11. SUPPRESSION UNIT CENTERED BETWEEN BURNERS, FRONT BURNER
GAS RANGE, FRY PAN 10-INCH (Stainless Steel)

TEST 1		TEST 2		TEST 3		TEST 4		TEST 5	
Veg Oil		Veg Oil		Peanut Oil		Veg Oil		Peanut Oil	
1/4"	**** T-84 Put Out	T-85 Did Not Put Out		**** T-86 Did Not Put Out		T-103 Put Out Reignition 40 sec		+ T-104 Put Out Reignition 30 sec	
1/2"	* T-60 Put Out Reignition 1 min 33 sec	* T-61 Put Out Reignition 1 min 36 sec		* T-62 Put Out Reignition 1 min 26 sec		** T-68 Did Not Put Out		*** T-69 Put Out No Reignition	
3/4"	* T-63 Put Out Reignition 10 sec	T-64 Put Out Reignition 6 sec		* T-65 Put Out Reignition Immediately					
2"									

* Splash caused fire under burner

** Burner turned off immediately

*** Burner turned off in 5 seconds

**** Burner was extinguished; test terminated immediately

+ Vegetable Oil.

TABLE 12. SUPPRESSION UNIT CENTERED BETWEEN BURNERS, FRONT BURNER
GAS RANGE, SAUCE PAN 7 1/4-INCH (Stainless Steel)

TEST 1		TEST 2		TEST 3		TEST 4		TEST 5	
Veg Oil		Veg Oil		Peanut Oil		Veg Oil			
1/4"	** T-87 Did Not Put Out	** T-88 Did Not Put Out		T-86A Did Not Put Out					
1/2"	* T-66 Put Out Reignition Immediately	* T-67 Put Out Reignition Immediately				** T-108 Put Out Reignition Immediately			
1"									
2"	T-130 Put Out Reignition Immediately	T-131 Put Out Reignition Immediately				T-132 Put Out Reignition Immediately			

* Excessive heat due to thermal draft

** Burner was extinguished

TABLE 13. SUPPRESSION UNIT CENTERED BETWEEN BURNERS, FRONT BURNER
GAS RANGE, SAUCE PAN 10-INCH (Stainless Steel)

TEST 1		TEST 2		TEST 3		TEST 4		TEST 5	
Veg Oil		Peanut Oil		Peanut Oil		Veg Oil		Veg Oil	
1/4"	T-133 Put Out Reignition 2 min 52 sec	T-135 Put Out Reignition 1 min 30 sec				T-134 Put Out Reignition 50 sec			
1/2"	T-70 Put Out Reignition 17 sec	T-71 Put Out Reignition 57 sec	T-72 Put Out Reignition 42 sec						
1"									
2"	T-127 Put Out Reignition 2 sec					T-128 Put Out Reignition 1 min 30 sec	T-129 Put Out Reignition 1 min 53 sec		

2. Extinguishers Above Each Burner

Tables 14 - 18 describe Range Queen tests where the units were placed directly above each burner. Placing the units above the burner, results in more agent in the pan. The advantage of getting more agent in the pan, is clearly seen by comparing Tables 6 and 16. Placing the extinguisher above the burner, doubles the time to reignition for 1/2 inch of oil in the 10 1/2-inch sauce pan on the large electric burner.

Although locating Range Queen units above each burner improves fire suppression performance, this arrangement also increases the probability of oil splash-out.

D. RESULTS (SCREENED RANGE QUEEN UNITS)

This section documents the results of tests conducted using "screened" Range Queen extinguishers (12 tests). All 12 tests were conducted with the units located directly over the burners. Two different screened Range Queen units were tested. The two models differ only with respect to the screen opening size (1/8 vs. 1/4 inch). All tests were conducted on the gas range. Test results are documented in Tables 19 and 20.

By comparing the results of Table 11 to those of Table 19, and the results of Table 13 to those in Table 20; it can be concluded that the "screened" units provided no more protection than the standard Range Queen units centered between burners. At least one or two of the agent outlet ports failed to open in each test. A significant quantity of agent remained trapped in the extinguisher, defeating the purpose of placing the unit over the burner. The only advantage of the screen is the reduction in splashout.

TABLE 14. SUPPRESSION UNIT OVER BURNER, LARGE BURNER
ELECTRIC RANGE, FRY PAN 10-INCH (Cast Iron)

TEST 1		TEST 2		TEST 3		TEST 4		TEST 5	
Veg Oil									
1/4"									
1/2"									
3/4"	T-13 Did Not Put Out *								
2"									

* Oil splashed out and continued to burn around pan; then fire returned to the pan

TABLE 15. SUPPRESSION UNIT OVER BURNER, LARGE BURNER
ELECTRIC RANGE, FRY PAN 13-INCH (Cast Iron)

TEST 1		TEST 2		TEST 3		TEST 4		TEST 5	
Veg Oil		Peanut Oil							
1/4"	T-8 Put Out No Reignition								
1/2"	T-9 Put Out No Reignition								
1"	T-10 No Ignition *	T-59 No Ignition *							
2"									

* Since no ignition occurred, data from these tests are included with suppression unit centered between burners.

TABLE 16. SUPPRESSION UNIT OVER BURNER, LARGE BURNER ELECTRIC RANGE, SAUCE PAN 10 1/2-INCH (Stainless Steel)

TEST 1		TEST 2		TEST 3		TEST 4		TEST 5	
Veg Oil		Veg Oil							
1/4"	T-7 Put Out No Reignition								
1/2"	T-6 Put Out Reignition 7 min	T-5 Put Out Reignition 6 min 40 sec							
1"	T-11 Put Out Reignition 4 min 10 sec								
2"	T-12 Put Out Reignition 5 min 30 sec								

TABLE 17. SUPPRESSION UNIT OVER BURNER, SMALL BURNER ELECTRIC RANGE, SAUCE PAN 10 1/2-INCH (Stainless Steel)

TEST 1		TEST 2	TEST 3	TEST 4	TEST 5
Veg Oil					
1/4"	T-2 Put Out No Reignition				
1/2"	T-3 Put Out No Reignition				
1"	T-4 Put Out No Reignition				
2"	T-14 No Ignition *	T-122 No Ignition *	T-123 No Ignition *		

* Since no ignition occurred, data from these test are included with suppression unit centered between burners.

TABLE 18. SUPPRESSION UNIT OVER BURNER, FRONT BURNER
GAS RANGE, FRY PAN 10-INCH (Stainless Steel)

TEST 1		TEST 2		TEST 3		TEST 4		TEST 5	
Veg Oil		Veg Oil		Veg Oil					
*	T-105 Put Out Reignition 50 sec		T-106 Put Out Reignition 40 sec	*	T-107 Put Out Reignition 18 sec				
1/4"									
1/2"									
3/4"									
2"									

* Three perforations on front of extinguisher only partially opened.

TABLE 19. SUPPRESSION UNIT OVER BURNER, FRONT BURNER
GAS RANGE, FRY PAN 10-INCH (Stainless Steel)

TEST 1		TEST 2		TEST 3		TEST 4		TEST 5	
Veg Oil		Veg Oil		Peanut Oil					
1/4"									
1/2"		* T-89 Put Out Reignition 1 min 11sec	** T-90 Put Out Reignition 29 sec	* T-91 Put Out Reignition 54 sec					
3/4"		** T-93 Put Out Reignition 20 sec	** T-94 Put Out Reignition 18 sec	* T-92 Put Out Reignition 13 sec					
2"									

* 1/4" Mesh Modified extinguisher

** 1/8" Mesh Modified extinguisher

On all test, 1 or 2 perforations on the extinguishers did not completely open.

TABLE 20. SUPPRESSION UNIT OVER BURNER, FRONT BURNER
GAS RANGE, SAUCE PAN 10-INCH (Stainless Steel)

TEST 1		TEST 2		TEST 3		TEST 4		TEST 5	
Veg Oil		Veg Oil		Peanut Oil					
1/4"									
1/2"	** T-95 Put Out Reignition 1 min 20sec	** T-96 Put Out Reignition 1 min 19 sec	* T-97 Put Out Reignition 1 min						
3/4"									
2"	* T-98 Put Out Reignition 5 sec	* T-99 Put Out Reignition 1 min 15 sec	** + T-100 Put Out Reignition 57 sec						

* 1/4" Mesh Modified extinguisher

** 1/8" Mesh Modified extinguisher

+ Three perforations on the extinguisher did not completely open.

SECTION IV

CONCLUSIONS

Range Queen extinguisher performance was found to be a function of several variables, including: range type (gas, electric), characteristics of the cooking vessel (geometry, size, material), burner size, burner location (front, rear), quantity of oil, cause of ignition, and extinguisher placement. More than 130 range-top fire tests were conducted to characterize the influence of each of these variables. The conclusions of this research effort are summarized below:

- This test program confirmed that Range Queen extinguishers (centered between burners) will initially extinguish many common range-top fires. However, if the heat source is not disconnected, reignition will occur in many cases.
- The agent/oil ratio is the key to initial extinguishment and sustained fire suppression. Fires are not extinguished and controlled unless the quantity of agent entering the pan is sufficient to neutralize the oil. Since Range Queen extinguishers contain only 8 ounces of agent (and only a portion of this actually enters the pan), they are capable of extinguishing only moderate volumes of burning oil.
- Range Queen units perform best on fires in large diameter, shallow fry pans, containing a limited amount of oil. (The specific amount of oil depends on the range type.) The large opening allows a significant quantity of agent to reach the oil. Fires in deep, small-diameter sauce pans are the most difficult to extinguish.
- Range Queen extinguisher performance is poor on gas ranges. Gas range burners supply more heat to the pan. Due to the greater heat source, gas range fires are more difficult to extinguish, and tend to re-ignite in a shorter period of time. In the current Air Force configuration (centered between burners) this unit is incapable of extinguishing a 5-ounce (1/4 inch) autoignited oil fire in a 7 1/4-inch sauce pan.
- Testing demonstrated that Range Queen extinguishers will extinguish the gas burner in certain situations. In several tests, the gas burner was extinguished, while the fire in the pan was not. Since the flow of gas continues after burner extinguishment, this phenomenon creates a potentially dangerous situation.
- Placing Range Queen units above each burner is not advisable. Although more agent does enter the pan, the agent often enters the pan with sufficient velocity to splash oil out of the pan. Splash-out often results in nearly immediate reignition on gas ranges. Also, depending on the geometry of the range hood, it is often impossible to locate units directly over the front burners.

- "Screened" Range Queen units offer little advantage. The performance of the screened units placed over the burners was basically the same as for standard units centered between burners. One or more agent outlet ports failed to open in each test. Since a significant quantity of agent remains trapped inside the extinguisher, this defeats the purpose of locating the extinguisher over the burner.